BELLCOMM, INC.

SUBJECT: Applications of Area Correlation Tracking to Planetary Flyby Subsystems and Experiments Case 103-2

DATE: January 6, 1967

FROM: E. H. Skeer

ABSTRACT

The Area Correlation Tracker (ACT) is an optical image scanning device capable of pattern recognition by statistical correlation of observed pattern data with a computer stored reference scene. In its present form the ACT has been designed for use in air-to-surface rocket systems to permit accurate guidance for weapons launching at remote low contrast targets. Employing modified correlation and control logic techniques, area correlation tracking is applicable to a number of flyby subsystems and experiments particularly in the areas of planetary photography, guidance, and on-board navigation.

This memorandum describes the ACT and discusses the implications of area correlation tracking for enhancement of flyby system operations.

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MEMORANDUM FOR FILE

The Area Correlation Tracker (ACT) is in principle an optical image scanning device which is capable of pattern recognition by statistical correlation of observed pattern data with a computer stored reference scene. The ACT is presently being developed for the Air Force Armament Laboratory by Martin Company's Orlando Division under the supervision of Dr. Lamar Harmon.

On November 22, the author visited Martin-Orlando for discussions with Dr. Harmon concerning possible applications of Area Correlation Tracking to planetary flyby subsystems and experiments.

In its present form the ACT has been designed for use in air-to-surface rocket and glide bomb systems to permit accurate guidance for stand-off weapons launching at passive targets, which include low contrast areas such as grain fields and dense foliage, as well as targets of relatively high contrast, such as buildings and bridges. The ACT is situated in the nose of the homing projectile, and in-flight, continuously compares a computer stored reference scene with a currently scanned area, and automatically makes compensations for closure, and pattern variations due to pitch, yaw, and roll shifts, as well as haze and intermittent cloud cover.

The ACT field of view is displayed to the command crew via an on-board vidicon which is directly coupled to the ACT optics. The initial reference scene is selected by the crew from the monitored field of view just prior to the time of triggering. The option exists for the crew to update the reference scene in subsequent portions of the flight.

In operation, continuous video signals are amplified and compared scan by scan with the reference signal pattern. By extrapolating past trajectory data a predictor continuously determines pitch, yaw, and roll inputs to the three axis gimballed optics and missile guidance systems during the homing run. The degree of tolerable target scene misalignment (i.e., forced drift due to aerodynamic buffeting) is in part dependent on scene contrast. This is because statistical correlation strength is a coupled function of signal/noise and reference - scan scene pattern overlap.

[redacted]

According to Dr. Harmon, the pointing accuracy of the scanning mode can in theory match the diffraction limit of the system optics. However, for the purposes of the present design this was not a requirement and has not been attempted.

The ACT is ultimately to be designed to fit into a 4-in. diameter configuration compatible with advanced missile and rocket designs and will weigh well under 100 pounds.

At the current stage of development, the system has been successfully designed for operation under the severe conditions of aerodynamic buffeting experienced by missiles at high velocity. Flight tests through mist and fog has been run using a breadboard model, and have verified ACT operational capability. Under most field conditions "low contrast" scenes have yielded excellent correlation data; tests have indicated that in operation the ACT logic system can literally distinguish one random patch of grain from another.

The ACT, employing modified correlation data processing and control logic techniques, is considered by Dr. Harmon to be applicable to a number of flyby subsystems. Among the applications that are considered feasible are:

1. Star Field Tracking - A single star field tracker can detect drift in the three rotational degrees of freedom simultaneously. Potential system accuracy of the star field tracker is not bounded by structural cross coupling and possible misalignments inherent in multiple element star track systems. Star field tracker system weight and complexity should be less than that of present multiple, single degree of freedom star trackers.

2. Image Motion Compensation - Image motion compensation (IMC) is required during short film exposure times so that blurring will not result from the relative motion of the object and camera systems. The demonstrated ability of the ACT predicator logic system to compensate for continuous pitch, yaw, roll, and range closure could be applicable for rapid sequence, out of (orbital) plane photography (i.e., with simultaneous pitch, yaw, and roll IMC components) during near encounter with the planet.

   It should be noted that there is a significant difference between IMC techniques for Lunar Orbiter (in which case the orbit is accurately predicted after several passes) and IMC required for a "single pass" planetary flyby telescope or camera system. In the case of the latter, precise preprogrammed IMC is not possible. Anomalies due to trajectory perturbations must be recognized and predicted moments before exposure time. The ACT successfully encounters the difficult problem of image compensation during high frequency aerodynamic buffeting and should be well suited for predicting low frequency flyby perturbations.

3. Surface Tracker - For stereoscopic photography of a selected site, several exposures with approximately 60% overlap are desirable. The ACT could track low contrast surface features and maintain a selected scene in the field of view of the flyby camera system for the entire time that the scene is in the direct line of sight of the camera.

4. Navigation Aid - According to Ref. 1, measurement noise and bias errors associated with use of an Apollo type sextant are highly dependent on the skill and experience of the sextant operator. Furthermore, the accuracy achieved with the best operators is significantly poorer than the diffraction limit of the instrument. Using an ACT to track reference landmarks (in lieu of selected sightings by man) should yield marked increase in on-board navigation accuracy.

In addition to subsystems implementation, possible experimental system applications of the ACT include the following operations:

1. Soft Landed Weather Station - The ACT, mounted on a stable platform aboard a soft lander, could track cloud patterns and/or lofted balloons across the horizon.

2. Glide-bomb - Fired to an altitude of several miles or dropped from balloons, the ACT, mounted in glide-bomb, could survey the near planet environment or home in on selected targets. This might be particularly interesting for Venus experiments because of the planets extremely dense atmosphere. (Here the ACT could operate in the IR as well as the visible region.) The ability to achieve high resolution in the glide mode depends on the ability to compensate for image motion along an arbitrary vector using a light weight IMC system. This has been successfully demonstrated in ACT operations.

M. H. Skeer

1013-MHS-nmm

Attachments
(see next page)

Attachment
Reference

Copy to
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REFERENCE

1. Lampkin, B. A., Navigator Performance Using a Hand-Held Sextant to Measure the Angle Between a Moving Line of Sight to a Flashing Light and a Simulated Star, Ames Research Center, Informal Symposium AAS, Space Flight Mechanics Committee, Valley Forge, Pennsylvania, October, 1966.